

CLAIMS

What is claimed as new and desired to be protected by Letters Patent of the United States is:

5/20/03

1. A method of forming a microstructure by micromachining, comprising:
providing a contoured substrate comprising an etchable material in a processing chamber;
generating a stable ion-containing etching plasma in said processing chamber, which etches said substrate;
generating a magnetic field, said magnetic field being adjustable in intensity and direction;
applying an RF bias power to said substrate, said RF bias power being adjustable in intensity;
controlling said etching of said substrate by said plasma by adjusting at least one of said magnetic field intensity, magnetic field direction, and RF bias power intensity during said etching.

2. The method of claim 1, further comprising adjusting at least said magnetic field intensity and said magnetic field direction during said etching.

3. The method of claim 1, further comprising adjusting at least said magnetic field intensity and said RF biasing power during said etching.

4. The method of claim 1, further comprising adjusting at least said magnetic field direction and said RF biasing power during said etching.

5. The method of claim 1, further comprising adjusting at least two of the magnetic field intensity, the magnetic field direction, and the RF biasing power simultaneously.

6. The method of claim 1, further comprising adjusting the magnetic field intensity, the magnetic field direction, and the RF biasing power simultaneously

7. The method of claim 1, wherein said plasma comprises free electrons and ions, said method further comprising adjusting at least one of said magnetic field intensity and direction to effect the path of travel of said free electrons whereby a plurality of said electrons form a high negative charge density region on said substrate; and
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adjusting said RF biasing power to effect the velocity of said ions toward said substrate, wherein said velocity of said ions is also effected by said high negative charge density region.

8. The method of claim 1, further comprising adjusting at least two of said magnetic field intensity, said magnetic field direction and said biasing power and as a function of time.

9. The method of claim 8, further comprising adjusting said magnetic field intensity and said magnetic field direction.

10. The method of claim 8, further comprising adjusting said magnetic field intensity and said RF bias power.

11. The method of claim 8, further comprising adjusting said magnetic field direction and said RF bias power.

12. The method of claim 1, wherein said etchable material comprises silicon oxide.

13. The method of claim 1, wherein said etchable material comprises silicon nitride.

14. The method of claim 1, wherein said contoured substrate comprises at least one depressed area within said substrate.

15. The method of claim 14, wherein said depressed area comprises a trench.

16. The method of claim 14, wherein said depressed area comprises a hole.

17. The method of claim 1, wherein said contoured substrate comprises at least one substrate protrusion of said substrate.

18. The method of claim 17, wherein said at least one protrusion comprises a pillar.

19. The method of claim 1, further comprising generating said plasma from a noble gas.

20. The method of claim 1, further comprising generating said plasma from a fluorocarbon gas.

21. The method of claim 1, further comprising generating said plasma from an oxygen gas.

22. The method of claim 1, further comprising generating said plasma from a carbon chloride gas.

23. The method of claim 1, wherein said magnetic field is strong enough to effect the path of travel of free electrons, but too weak to effect the path of ions of said plasma.

24. The method of claim 1, further comprising generating said magnetic field with permanent magnets.

25. The method of claim 1, further comprising generating said magnetic field with electric coils.

26. The method of claim 1, further comprising applying an RF bias power in a range between about 0 watts and about 5000 watts.

27. The method of claim 1, further comprising biasing said substrate with an inductive power in a range between about 300 watts and about 10,000 watts.

28. A method of forming a fabricated device, comprising:
providing a contoured workpiece;
generating a stable plasma, said plasma comprising free electrons and ions, said free electrons having a velocity toward said workpiece;
generating a magnetic field at said workpiece and within said plasma;

forming a high negative charge density region on a contoured region of said workpiece by effecting the path of travel of said free electrons with said magnetic field;

changing the location of said high negative charge density region by changing a direction of said magnetic field while etching said workpiece with said plasma.

29. The method of claim 28, further comprising applying an RF bias power to said substrate during said etching.

30. The method of claim 28, wherein said magnetic field is strong enough to effect the path of travel of said free electrons, but not strong enough to effect the path of said ions.

31. The method of claim 28, further comprising controlling said magnetic field in at least one of its intensity and direction relative to said workpiece, during said etching to alter the path of travel of said free electrons.

32. The method of claim 28, further comprising adjusting the RF bias power to effect the velocity of said ions toward said workpiece during said etching.

33. The method of claim 28, further comprising adjusting said magnetic field intensity and said magnetic field direction during said etching.

34. The method of claim 28, further comprising adjusting said magnetic field intensity and said RF bias power during said etching.

35. The method of claim 28, further comprising adjusting said magnetic field direction and said RF bias power during said etching.

36. The method of claim 28, further comprising adjusting at least one of said magnetic field intensity and direction and said RF bias power relative to each other and as a function of time during said etching.

37. The method of claim 34, further comprising adjusting said magnetic field intensity and said RF bias power simultaneously during said etching.

38. The method of claim 35, further comprising adjusting said magnetic field direction and said RF bias power simultaneously during said etching.

39. The method of claim 28, further comprising rotating one of said workpiece and said magnetic field relative to the other.

40. The method of claim 28, wherein said workpiece comprises a layer of an insulating material which is etched by said plasma.

41. The method of claim 40, wherein said fabricated device is formed in said layer of insulating material.

42. The method of claim 41, wherein said insulating material comprises silicon oxide.

43. The method of claim 41, wherein said insulating material comprises silicon nitride.

44. The method of claim 28, wherein said contoured workpiece comprises at least one depressed area within said workpiece

45. The method of claim 44, wherein said depressed area comprises a trench.

46. The method of claim 44, wherein said depressed area comprises a hole.

47. The method of claim 28, wherein said contoured workpiece comprises at least one workpiece protrusion.

48. The method of claim 47, wherein said workpiece protrusion comprises a pillar.

49. The method of claim 28, further comprising generating said magnetic field with permanent magnets.

50. The method of claim 28, further comprising generating said magnetic field with at least one electric coil.

51. The method of claim 29, further comprising applying said RF bias power to said workpiece in a range between about 0 and about 500 watts.

52. The method of claim 29, further comprising applying an inductive power to said substrate in a range between about 300 and about 10,000 watts.

53. A method of plasma etching a material layer to form a microstructure, comprising:
providing a material layer having at least one contour;
flowing gas into a chamber containing said material layer;
generating a stable etching plasma from said gas, wherein said plasma comprises free electrons and ions;
etching said material layer with said plasma; and
varying the location of said etching of said material layer during said etching by varying the location of impingement of said free electrons.

54. The method of claim 53, further comprising varying said location by generating a magnetic field within said chamber and varying the direction of said magnetic field.

55. The method of claim 53, wherein said material layer comprises a silicon oxide layer.

56. The method of claim 53, wherein said material layer comprises a silicon nitride layer.

57. The method of claim 53, wherein said material layer comprises at least one depressed area with said material area.

58. The method of claim 57, wherein said depressed area comprises a trench.

59. The method of claim 57, wherein said depressed area comprises a hole.

60. The method of claim 53, wherein said material layer comprises at least one protrusion.

61. The method of claim 60, wherein said protrusion is a pillar.

62. The method of claim 53, further comprising generating said plasma from a gas selected from the group consisting of noble gases, fluorocarbons, oxygen, carbon chlorides, or mixtures thereof.

63. The method of claim 64, further comprising generating said magnetic field to be strong enough to influence the velocity of said free electrons, but weak enough not to influence the path of said ions.

64. The method of claim 63, further comprising generating said magnetic field by permanent magnets.

65. The method of claim 63, further comprising generating said magnetic field by at least one electric coil.

66. A method of forming a plasma etched device, comprising:
providing a contoured workpiece comprising an insulating material in a plasma chamber;
generating a stable plasma within said chamber from a gas flow, said plasma comprising free electrons and ions, said free electrons having a path of travel toward said workpiece, said ions etching said workpiece;
generating a magnetic field at said workpiece and controlling said magnetic field in intensity and direction to vary the location of impingement of said free electrons on said workpiece, the location and impingement of said ions on said workpiece being affected by the location of impingement of free electrons on said workpiece; and
applying an RF bias power to said workpiece during ion etching and adjusting, said RF bias power during etching to vary the intensity of etching.

67. An apparatus for plasma etching a workpiece, said apparatus comprising:
a plasma etching chamber which includes a workpiece holder;
a magnetic field source for generating a directional magnetic field of adjustable intensity into said chamber, at least one of said workpiece holder and magnetic field source being movable relative to the other to change the direction of said magnetic field relative to a workpiece placed on said holder;

an adjustable RF bias source for providing an adjustable RF bias to a workpiece on said holder; and a controller capable of adjusting at least one of the magnetic field direction, the magnetic field intensity and the RF bias during an etching operation conducted within said chamber.

68. The apparatus of claim 67, wherein said magnetic field source comprises permanent magnets.
69. The apparatus of claim 67, wherein said magnetic field source comprises electro magnets.
70. The apparatus of claim 67, wherein said workpiece holder is adjustable relative to said magnetic field source.
71. The apparatus of claim 67, wherein said magnetic field source is adjustable relative to said workpiece holder.
72. The apparatus of claim 67, wherein said controller is capable of adjusting said magnetic field direction during an etching operation.
73. The apparatus of claim 67, wherein said controller is capable of adjusting said magnetic field intensity during an etching operation.
74. The apparatus of claim 67 wherein said controller is capable of adjusting said RF biasing during an etching operation.
75. The apparatus of claim 67, wherein said controller is capable of adjusting at least two of said magnetic field direction, said magnetic field intensity and said RF bias during an etching operation.
76. The apparatus of claim 67, wherein said controller is capable of adjusting all three of said magnetic field direction, said magnetic field intensity and said RF bias during an etching operation.
77. The apparatus of claim 67, wherein said controller is programmable.